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An Empirical Examination of Fama-French Five-Factor on Green Tech Stock

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Abstract: *This research investigates the influence of the Fama-French Five-Factor Model—comprising market risk premium, firm size, book-to-market equity, profitability, and investment—on green technology stock returns across developed and developing markets, specifically in Malaysia, the United States, and China. This quantitative study will use monthly time-series data from January 2017 to December 2023 to analyse the impact of the Fama-French Five Factors (FF5) on green tech stock returns in Malaysia, China, and the United States. Data will be sourced from S&P Capital IQ, and modern econometric software will be used to regress the independent variables (FF5 factors) on the dependent variable (portfolio returns). Since the study period includes the COVID-19 pandemic, this research also investigates how the pandemic influenced the relationships between risk factors and green tech stock returns. Using a comparative approach, it analyses the varying effects of the five risk factors on green tech stock returns in both emerging and developed economies. This analysis seeks to provide comprehensive insights into the risk-return dynamics of green tech investments, which are crucial for optimising investment portfolios in the face of climate change and economic disruptions caused by the pandemic. The findings of this study will offer valuable implications for investors, policymakers, and green tech companies, highlighting the importance of robust risk management and informed decision-making to foster sustainable financial and environmental outcomes.*

Keywords: Fama-French five factors model, Green-Tech Stock, COVID-19

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1. Introduction

Investing in the share market is widely perceived as a pathway to wealth accumulation and financial growth. Historically, stock market investments have delivered attractive returns over the long term. For instance, according to a study by Ibbotson Associates, the average annual return of the S&P 500 index from 1926 to 2020 was approximately 10% (Ibbotson & Sinquefield, 2021). Such statistics underscore the potential of equity investments to generate substantial wealth over time. However, investing in the stock market is inherently volatile, and individual investors often underperform due to poor timing and emotionally driven decisions. Dalbar Inc.'s study reveals that average investors consistently lag behind market returns, largely due to these behavioural influences. Understanding risk factors is essential for investors to improve returns and manage risks effectively.

The evolution of models to predict stock performance has yielded key frameworks that guide investors, researchers, and policymakers in understanding risk-return relationships. The

foundational Capital Asset Pricing Model (CAPM), developed by William Sharpe in the 1960s, links expected stock returns to market risk, with beta (β) as a measure of a stock's sensitivity to market movements, thereby associating higher risk with higher expected returns. Expanding beyond CAPM, Stephen Ross's Arbitrage Pricing Theory (APT) introduced in 1976 incorporates multiple factors, such as interest rates and economic growth, offering a more nuanced view by considering a variety of economic and market influences.

Further refining these models, Eugene Fama and Kenneth French's Three Factor Model (1992) added size and value factors to improve the analysis of stock returns beyond market risk. Mark Carhart's Four Factor Model (1997) added momentum, capturing short-term performance trends often observed in stocks. Building on this work, Fama and French's Five Factor Model (2015) includes profitability and investment factors, providing a more comprehensive tool for examining stock performance by considering company-specific financial health and investment behaviours. Together, these models progressively enhance the understanding of the complex factors driving stock returns.

As climate change awareness grows, investors are increasingly incorporating climate-related factors into their strategies, impacting market valuations and aligning with a global shift toward a greener economy and projected returns on Green Tech stocks. Companies face escalating pressures from environmental challenges and competitive markets, driving them to adopt sustainable practices and focus on green technology to address both environmental and financial performance goals (Lubberink et al., 2017; El-Kassar et al., 2019). Highlighted by initiatives like COP26 (Conference of the Parties hosted in Glasgow in year 2021), green finance, particularly climate finance, has become essential for supporting adaptation and resilience against climate change (Dogan et al., 2022). This shift toward a net-zero economy demands urgent financial investment across diverse sources (United Nations Climate Change, 2021). The green finance market, bolstered by renewable energy investment, offers economic and environmental benefits, with commitments like the Glasgow Climate Convention targeting a low-carbon economy post-2025 (United Nations Climate Change, 2021). For investors, the transition presents valuable opportunities, especially through diversification in fintech, green bonds, and renewable energy, providing resilience amid market volatility (Koutmos, 2018; Shahzad et al., 2019; Gil-Alana et al., 2020; Le et al., 2021).

Beginning in late 2019, COVID-19 caused global market disruptions, resulting in heightened volatility as investors navigated the uncertainty from government-imposed lockdowns and restrictions (Ding et al., 2021). Markets saw drastic declines, such as the S&P 500's 33% drop from February to March 2020, with similar downturns in markets worldwide, including China and Germany (World Health Organization, 2020; Fernandes, 2020). Research indicates that COVID-19 amplified volatility and trading volumes in stock markets as investors adjusted to lockdown conditions, influenced by pandemic-driven fluctuations in investor sentiment and sector performance. For instance, while sectors like food retail saw relatively stable stock prices, others faced more volatility due to the crisis (Chatjuthamard et al., 2021; Hoffmann et al., 2013; Höhler & Lansink, 2021). Evidence also suggests a negative relationship between COVID-19 case growth and stock returns, attributed to increased market risk and investor uncertainty, especially during early pandemic stages (Xu, 2021; Chatjuthamard et al., 2021; Phan & Narayan, 2020).

Despite this potential, research on how traditional asset pricing models apply to Green Tech stock performance remains limited (Dogan et al., 2022). This study addresses this gap by examining the model's impact on Green Tech stocks across Malaysia, the United States, and

China, offering insights into the interaction between green tech stocks and the Fama-French framework in varied market environments. Additionally, this study aims to explore how COVID-19 impacts the relationship between standard risk factors (market risk premium, size, value, profitability, and investment) and Green Tech stock performance.

Section 2 offers a thorough review of prior research, discussing the historical development of the theoretical foundations relevant to this study. It also introduces the conceptual framework that guides the research approach and presents the development of the hypotheses to be examined. Section 3 then provides an in-depth explanation of the research methodology, outlining the study's design, procedures for data collection, sampling techniques, definition of the data population, and the methodological framework that supports the analysis.

2. Literature Review

Asset portfolio optimization seeks a balance between risk and return. Harry Markowitz introduced portfolio theory in 1952, showing how risk-averse investors can build portfolios for optimal returns at a given risk level. A decade later, during the early 1960s, (Sharpe, 1964; Litner, 1965; Mossin, 1966) formulated an asset pricing model grounded in Markowitz's portfolio theory (Juniawan Mandala et al., 2023). The CAPM (Capital Asset Pricing Model) represents a progression from Markowitz's portfolio theory, introducing the concepts of systematic risk and specific/unsystematic risk. This model uses something called beta to measure systematic risk, which is a type of risk you can't avoid by diversifying your investments. It does this by comparing how a stock's returns change compared to the overall market. This is often called the single-factor model.

However, recent discoveries suggest that the CAPM might not explain all the different and unexpected things that happen in the world of investments. The CAPM has become a central tool in finance for estimating a firm's cost of capital by associating returns with market (systematic) risk, which can't be eliminated through diversification. Barillas and Shanken (2015) emphasise CAPM's utility in assessing portfolio performance, while Hendershott et al. (2020) explain that CAPM links returns solely to systematic risk, ignoring asset-specific risks. Andrei et al. (2022) highlight CAPM's linear correlation between risk and return, with beta as the measure of systematic risk. Despite its widespread use, critics argue that CAPM's assumptions—such as single-period planning, no taxes, and investor homogeneity—are unrealistic in practice, as shown in empirical tests in Asian markets by Bark (1991) and Cheung et al. (1993), where CAPM performed poorly. Nevertheless, CAPM remains influential theoretically, even as alternative models by Fama and French (3-factor and 5-factor models) and Hou et al. (4-factor model) attempt to address its limitations.

In 1993, Fama and French introduced the three-factor model to improve upon the CAPM, which struggled to accurately predict stock returns. They identified that CAPM missed two key risks: size and value factors (Rohuma, 2023). To address this, Fama and French (1993) constructed and added two factors to simulated portfolios, representing the size and value effects of the CAPM factor (Market Risk Premium, MRP). These two factors are: (1) the small-cap risk premium (SMB), which is a simulated portfolio of size-related risk factors that represents the difference in returns between small- and large-cap stocks; (2) the value risk premium (HML), which is a simulated portfolio of value-related risk factors representing stocks with higher book to market value BVTMV (value stocks) and stocks with lower BVTMV (growth stocks). It's important to note that, in general, small-cap stocks tend to have higher returns than large-cap stocks (Banz, 1981; Arnaya & Purbawangsa, 2020). Similarly,

value stocks typically show higher returns compared to growth stocks (Fama & French, 1993; Black et al., 2009; Cao et al., 2017). These additions allow investors to account for and potentially benefit from the risks tied to stock size and value.

Empirical studies by Taneja (2010), Basiewicz and Auret (2010), and Sattar (2017) show that the three-factor model offers significant improvements over the single-factor CAPM in explaining variations in stock returns. While the three-factor model better accounts for average excess returns, unresolved anomalies persist, as noted by Eraslan (2013), Novy-Marx (2013), and Titman, Wei, and Xie (2004). These studies indicate that additional factors may still be needed to fully explain residual variations in returns.

In the early 1990s, Carhart enhanced the Fama-French three-factor model by introducing a momentum factor, aiming to improve its ability to explain expected returns. Both the Fama-French three-factor model and the Carhart four-factor model are seen as more robust than the CAPM for explaining average stock returns, but literature remains divided on which model is superior. Czapkiewicz and Wójtowicz (2014) argue that the Carhart model has better explanatory power on the Warsaw Stock Exchange, while Sakowski et al. (2015) find it reliable for predicting returns across developed markets. In emerging markets, Osagie and Osamwonyi (2017) assert that the Carhart model outperforms the Fama-French model in Nigeria, but Shaker and Abdeldayem (2018) offer contrasting results from Egypt. This suggests that the effectiveness of these models varies by country in emerging markets, potentially due to unique characteristics such as volatility and illiquidity (Boamah, 2015). Thus, systematic conclusions about model applicability in specific contexts require localised testing.

Fama and French (2015) enhanced their three-factor model by adding two new factors: profitability and investment, drawing from empirical evidence that highlighted their significant effects on asset returns. In their five-factor model, profitability is calculated as net income divided by book equity, while investment is assessed based on the growth in total assets. Their testing of the model using data from July 1963 to December 2013 in the U.S. market demonstrated that the five-factor model outperforms the three-factor model by explaining more anomalies in asset returns, as noted by Chiah et al. (2016).

Fama and French (2015) also examined the five-factor model's applicability in various international markets, including North America, Europe, Japan, and Asia Pacific. They concluded that the model effectively accounts for most anomaly patterns in average capital market returns. In a study of the Chinese stock market, Guo et al. (2017) found that size, value, and profitability significantly influenced average returns, whereas the investment factor had a lesser impact. Overall, empirical studies reveal that the performance of the five-factor model varies across regions. While some studies, such as those by Chiah et al. (2016) and Guo et al. (2017), support the five-factor model over its predecessor, others, including Racicot and Rentz (2017) and Dutta (2019), reject it. These mixed results may stem from the unique characteristics of different markets.

This study examines the impact of the Fama-French Five-Factor Model—which includes market risk premium, firm size, book-to-market equity, profitability, and investment—on green technology stock returns across both developed and emerging markets, focusing on Malaysia, the United States, and China. Hypotheses are developed to explore the relationships between these risk factors and green tech stock returns.

Market risk premium has been a central focus in asset pricing model research, defined as the difference between the expected return on the market portfolio and the risk-free rate. Investors seek compensation for taking risks and for potential missed opportunities, often referred to as opportunity costs. The risk-free rate, typically associated with the interest on a risk-free or zero-risk investment, is commonly represented by the long-term yields on national government bonds due to their low default risk. Clare and Priestley (1998) conducted an empirical study in emerging markets, finding a significant relationship between market premium and average stock returns in regions like Hong Kong, Malaysia, and Singapore. Additionally, the market risk premium accounts for a substantial portion of the cross-sectional variation in average returns, explaining 57% of R^2 when considering time-varying beta (Jagannathan and Wang, 1993). This strong correlation with macroeconomic indicators suggests that the market risk premium fluctuates with the business cycle and other economic conditions. Therefore, when using this factor to explain expected returns, it is crucial to consider its temporal variations. In this context, hypotheses regarding the market risk premium are proposed as follows:

H1a: Market risk premium positively affects green tech stock return in Malaysia, the United States, and China.
H1b: There is a significant mean difference on how market risk premium affects green tech stock return between Malaysia, the United States, and China.

Firm size, measured by market capitalization, influences excess returns and is captured by the SMB (Small Minus Big) factor, which reflects the historical outperformance of small-cap companies over large-cap ones. The premise is that small-cap companies generally yield higher returns in the long run, as first documented by Banz (1981). Since then, the size effect has been studied extensively and incorporated into multifactor models like the Fama and French three-factor model (1993), widely used in asset pricing. Research supports this effect, particularly in the 1980s and 1990s, showing small firms often outperform larger ones (Chan et al., 1997; Dichev, 1998; Amihud, 2002). However, evidence on the size effect varies over time. For instance, Hirshleifer (2001) found a strong small-cap effect in the 1974–1983 period, which turned negative from 1984–1991. Schwert (2003) reported the effect disappeared after 2000, and Hou and Van Dijk (2019) found it significant only from 1963 to 1982 but absent from 1983 to 2014. Hypothesis on firm size:

H2a: Firm size positively affects green tech stock return in Malaysia, the United States, and China.
H2b: There is a significant mean difference on how firm size affects green tech stock return between Malaysia, the United States, and China.

The value or growth equities in portfolio management have long historical evidence in financial economics. The world's famous retirement fund management company, Fidelity chooses stocks based on either being a good value (like finding a great deal) or showing strong growth potential. As such, there are different schools of thought in the view of value or growth. Benjamin Graham, known as the "father of value investing," focuses on finding good deals. On the other side, T. Rowe Price, the "father of growth investing," looks for stocks with high potential for future growth. It's like deciding between a fantastic sale and a promising future when you're deciding where to invest your money (Cronqvist et al., 2015).

The valuation of companies plays a significant role in stock returns, as highlighted by the Fama-French Three-Factor (FF3) model, which includes a "high minus low" (HML) or value premium factor. HML represents the return difference between companies with high and low

book-to-market ratios, where value stocks (high book-to-market) are expected to outperform growth stocks (low book-to-market) over time. The literature identifies two main value premium types: earnings yield (E/P) and book-to-price (B/P) ratio. Evidence for the E/P premium is documented across U.S. and non-U.S. markets. Basu (1983) first identified the E/P premium in the U.S., with findings later affirmed by researchers such as Fama and French (1992) and Israel and Moskowitz (2013). Similarly, studies outside the U.S., like those by Hart et al. (2005) and Hou et al. (2011), confirm E/P's role in explaining returns. For the B/P premium, studies in the U.S. (e.g., Stattman, 1980; Fama & French, 2012) show a consistently positive impact on returns. This trend holds across 23 developed markets globally, where Fama and French (2012) observed similar patterns across North America, Japan, Asia Pacific, and Europe. In this regard, hypothesis of firm's value is set as follow:

H3a: Firm value positively affects green tech stock return in Malaysia, the United States, and China.
H3b: There is a significant mean difference on how firm value affects green tech stock return between Malaysia, the United States, and China.

To address unexplained anomalies in asset pricing, Fama and French introduced additional factors—profitability and investment—as indicators for average returns. Their tests on book-to-market, profitability, and investment factors, along with insights from the dividend discount model, aimed to address limitations of the CAPM. Researchers like Haugen et al. (1996) and Cohen et al. (2002) also highlighted the significant role of profitability in average returns.

Furthering this work, Novy-Marx (2013) proposed gross profitability as a superior predictor of stock returns compared to current earnings. Gross profitability, unlike current earnings, excludes expensed investments, which provides a clearer reflection of profitability's impact on value premiums. This approach showed a strong, negative correlation between gross profitability and book-to-market ratios, suggesting that controlling for one could enhance the other's performance. In Japan, Kubota and Takehara (2018) found that profitability and investment factors were less effective in explaining stock returns, casting doubt on the five-factor model's applicability there, while Racicot and Rentz (2017) also reported weak support for these factors. Additionally, Titman et al. (2004) noted a negative relationship between investment and future stock returns. This study thus sets the following hypotheses:

H4a: Profitability positively affects green tech stock returns in Malaysia, the U.S., and China.
H4b: There are significant differences in how profitability affects green tech stock returns across these markets.
H5a: Investment factor positively affects green tech stock returns in Malaysia, the U.S., and China.
H5b: There are significant differences in how the investment factor affects green tech stock returns across these markets.

The onset of the COVID-19 pandemic brought considerable instability to global stock markets, with stock indexes swinging dramatically amid pandemic news. Initial panic led many investors to sell off assets rapidly, causing a sharp drop in market value. However, intervention by governments and central banks soon helped drive prices back up, though uncertainty persisted. Numerous studies have since examined COVID-19's effects on stock markets and corporate performance, revealing an increase in volatility and negative impacts on returns due to the pandemic's elevated risk environment.

Research highlights significant volatility spikes in multiple stock markets during early 2020 (Zhang et al., 2020), as well as negative returns in response to rising COVID-19 cases (Xu, 2021; Shen et al., 2020). Findings show a consistent negative relationship between COVID-19 case growth and stock returns, particularly at the firm level (Ding et al., 2021; Chatjuthamard et al., 2021). Further, COVID-19 has contributed to liquidity issues, with reduced corporate liquidity reported (De Vito & Gomez, 2020; Chebbi et al., 2021).

COVID-19 has amplified volatility through heightened uncertainty and investor sentiment. Studies also demonstrate a rise in trading volume during the pandemic (Chiah & Zhong, 2020), driven by the surge in available news and, likely, retail investors' increased trading activity during lockdowns. However, stock price declines due to COVID-19 could also reduce trading volume in some cases.

The increase in risk and uncertainty due to COVID-19 has generally been linked to lower stock returns (Aggarwal et al., 2021; Phan & Narayan, 2020). Consequently, this study seeks to explore COVID-19's impact on the relationship between key risk factors—market risk premium, firm size, value, profitability, and investment—and green tech stock performance, hypothesising that COVID-19 strengthens these relationships:

H6a: COVID-19 impact strengthens the relationship between market risk premium and green tech stock return.
H6b: COVID-19 impact strengthens the relationship between firm size and green tech stock return.
H6c: COVID-19 impact strengthens the relationship between firm value and green tech stock return.
H6d: COVID-19 impact strengthens the relationship between profitability and green tech stock return.
H6e: COVID-19 impact strengthens the relationship between the investment factor and green tech stock return.

The theoretical framework focuses on exploring the relationships between green tech stock performance and several independent variables, including market risk premium, firm size, firm value, investment, and profitability. It also examines how COVID-19 acts as an interaction effect that influences these relationships between the independent variables and green tech stock performance.

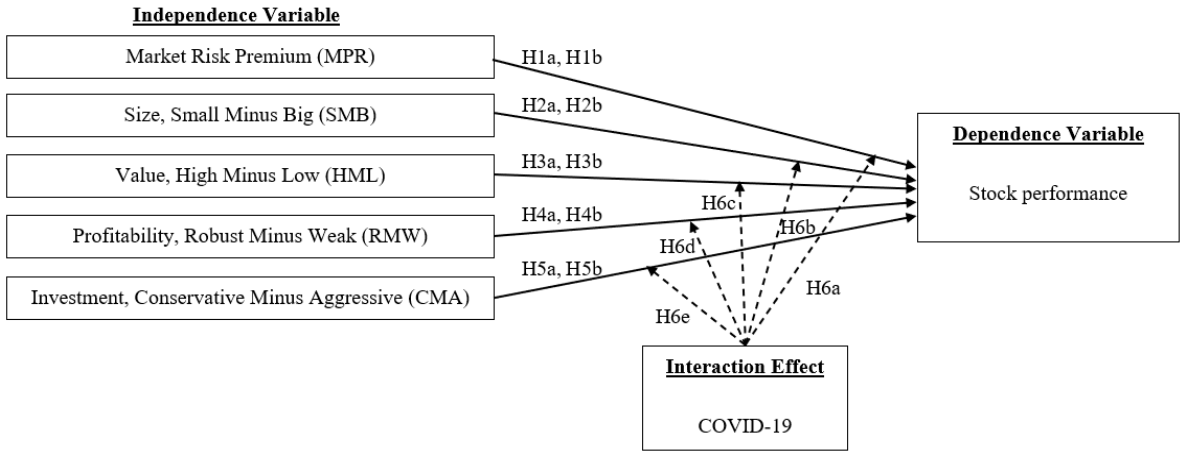

Figure 1: The framework illustrates the interaction between Green Tech Stock Performance and five risk factors, with interaction effect by COVID-19 impact.

3. Methodology

This study employs quantitative research using secondary data collection methods to analyse portfolio returns through multifactor analysis incorporating the Fama-French Five Factors (FF5). Data will be gathered from various stock exchanges and the International Monetary Fund (IMF), which provides reliable, standardised information for comparative analysis. The risk-free rate will be derived from monthly Treasury bill data from the IMF, while market capitalization will be calculated by multiplying outstanding shares by their monthly closing adjusted prices. Market returns will be assessed using indices from Malaysia (FTSE Bursa Malaysia KLCI Index), China (Shanghai Stock Exchange Index), and the United States (S&P 500 Index) over a period from January 2017 to December 2023. Additional data, including the Book to Market ratio, Operating Profitability, and Investment metrics, will be sourced from annual reports. Operating Profitability is calculated from annual revenue minus cost of goods sold, while Investment is determined by the change in total assets year-over-year. Data on green tech stocks will be obtained from S&P Global, known for its comprehensive and credible financial information. S&P Capital IQ, part of S&P Global, will facilitate detailed financial analysis with its robust datasets and analytical tools. Monthly COVID-19 case data will be sourced from Worldometer, transformed into dummy variables to assess their interaction effects on the relationship between risk factors and green tech stock performance. Worldometer is chosen for its reliable and current data, aiding rigorous statistical analysis. A summary of variable descriptions and data sources is provided in Table 1.

Table 1: Summary of the variable description and data sources

Data Variables	Description	Source
Risk Free Rate	Monthly Treasure bill of respective countries	International Monetary Fund (IMF)
Market Capitalization	Market capitalization of the month, using number of issued shares multiple with market share price	Country Stock Exchange data source
Stock Price	Monthly closing adjusted price	S&P Capital IQ
Market Return	The return of indices of countries respectively (FBMKLCI, SSE and S&P500)	
Book to Market Ratio	Ratio of book value over the market value	
Operating Profitability	Annual revenue minus cost of goods sold, interest expense and selling, general and administrative expenses, all divided by book value of equity	
Investment	Current year's total assets minus previous year's total assets and dividing the result by the current year's total assets.	
COVID-19	Monthly confirmed COVID-19 cases of respective country	Worldometer

The analysis will utilise modern econometric software to perform regression analysis, examining the relationship between the independent variables and portfolio returns. The study will select green tech stocks from the stock exchanges of Malaysia, China, and the United States, specifically from Bursa Malaysia, the Shanghai Stock Exchange, and the S&P 500, respectively. This selection aims to ensure a representative sample of green tech stocks from each market. As of 2017, Bursa Malaysia has 905 listed companies, while the Shanghai Stock Exchange features over 1,500, and the S&P 500 includes 503 companies. By filtering stocks from these diverse listings, the study will analyse a broad and representative sample of the green tech sector, allowing for a detailed examination of performance and dynamics across different economic environments and market structures.

The Fama-French five-factor model is applied to analyse Green Tech stocks listed on exchanges in Malaysia, China, and the United States, examining the impact of size, value, investment, and profitability factors. Portfolio returns are measured using Ordinary Least Squares (OLS) regression based on the following equation:

$$R_t = \alpha + \beta_1 Rm_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \varepsilon \ldots\ldots \text{Eq (3.1)}$$

Where dependent variable, R_t excess return representing the return on asset for month t minus the risk-free rate (Rf_t), where RF_t is the monthly Treasury bill rate of the respective countries; the independent variables include Rm_t, market return minus the risk-free rate; SMB_t, size factor (small minus high market capitalization); HML_t value factor (high minus low book-to-market ratio); RMW_t, operating profitability factor (robust minus weak), and CMA_t, investment factor (conservative versus aggressive investment). The coefficients β_1, β_2, β_3, β_4, and β_5 represent the values associated with the independent variables. OLS regression is chosen for its efficiency and simplicity in modelling these relationships.

Additionally, COVID-19 pandemic's effect is examined as an interaction variable on the relationship between key risk factors and green tech stock performance, recognizing that the pandemic may have altered market behaviour. To quantify COVID-19's influence, the study incorporates confirmed case counts from Malaysia, China, and the United States (Hsu & Liao, 2022), using the natural logarithm of monthly cases to normalise and compare the severity of the pandemic's progression across these regions. Equation (2) shows the regression for COVID-19 impact as interaction effect on the relationship between independent variables and dependent variable.

$$DV_t = \alpha + \beta_1 IV_t + \beta_2 IV_t * COVID19 + \varepsilon \ldots\ldots \text{Eq (2)}$$

Where DV_t is dependent variable; IV_t is independent variable; COVID19 impact act as interaction effect on the relationship between independent variable and dependent variable; β_1 and β_2 are coefficient values of the independent variables.

Before performing regressions using ordinary least squares (OLS) on time-series data, diagnostic tests are necessary to ensure model robustness. These tests help detect and correct issues like autocorrelation, heteroscedasticity, multicollinearity, and non-stationarity. Addressing these potential problems is crucial, as they could violate OLS assumptions, leading to biased and inefficient estimates.

4. Conclusion

This conceptual paper explores the application of the Fama-French Five-Factor Model, which includes the factors of market risk premium, size, book-to-market equity, profitability, and investment, to green technology stocks, with an emphasis on how COVID-19 has affected this sector. The Fama-French model has been extensively studied in the context of traditional stocks, but this research aims to extend its applicability to green tech stocks, which are increasingly important due to their alignment with sustainability objectives while also facing unique risks.

The study examines risk factors impacting green technology stocks in both developing and developed markets. Specifically, it focuses on green tech stocks from Bursa Malaysia and the Shanghai Stock Exchange to represent the dynamics of developing markets. Additionally, it

incorporates green tech stocks from the S&P 500 in the United States to provide a contrasting perspective from developed markets. This dual market analysis seeks to capture a wide array of market conditions, thus shedding light on the long-term implications for green tech stock returns.

One of the key objectives of the research is to bridge existing gaps in understanding the risk-return profiles associated with green tech investments, particularly under the increased volatility caused by the COVID-19 pandemic. Insights derived from this study are intended to aid investors in optimising their portfolios by understanding the unique dynamics of the green tech sector. Furthermore, the findings are expected to assist policymakers in shaping regulatory frameworks that encourage sustainable investments while maintaining market stability.

In an academic context, this study contributes to the literature by applying the Fama-French Five-Factor Model to the relatively underexplored domain of green technology stocks. By incorporating the effects of pandemic-related disruptions, the research enhances existing financial theories and lays the groundwork for future inquiries in sustainable finance and environmental economics.

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Abbreviations

APT: Arbitrage Pricing Theory.
BVTMV: Book Value-to-Market Value Ratio.
CAPM: Capital Asset Pricing Model.
CF4: Carhart Four-Factors Model.
CMA: Conservative Minus Aggressive.
FF3: Fama-French three-factor model.
FF5: Fama-French five-factor model.
HML: High Minus Low.
MRP: Market Risk Premium.
SMB: Small Minus Big.
RMW: Robust Minus Weak.